U.S. DEPARTMENT OF COMMERCE
National Technical Information Service
PB-289 378

Air Pollution Emissions Projecting. A Report of the NATO/CCMS Pilot Study on Air Pollution Assessment Methodology and Modeling

NATO Committee on the Challenges of Modern Society, Brussels (Belgium)

Oct 78

PB 289378

COMMITTEE ON
THE CHALLENGES OF
MODERN SOCIETY

AIR POLLUTION
ASSESSMENT METHODOLOGY and MODELLING

Number 100

Air Pollution Emissions Projecting

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U. S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

NORTH ATLANTIC TREATY ORGANIZATION

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO.	2.	3. RECIPIENT'S ACCESSION NO.
NATO/CCMS 100		PB289378

4. TITLE AND SUBTITLE	5. REPORT DATE
Air Pollution Emissions Projecting - A Report of the NATO/CCMS Pilot Study on Air Pollution Assessment Methodology and Modeling	October 1978
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S)	8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS North Atlantic Treaty Organization Committee on the Challenges of Modern Society Brussels, Belgium	10. PROGRAM ELEMENT NO.
	11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS North Atlantic Treaty Organization Committee on the Challenges of Modern Society Brussels, Belgium	13. TYPE OF REPORT AND PERIOD COVERED
	14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT

This document is concerned with alternative emission projection techniques and describes the relationship of emissions projecting to the Air Quality Management System (AQM). Based on the experience of several NATO countries, principles are given for applying the projecting techniques to the available emissions inventory data bases and to the other data required. The Appendix presents detailed methodology for emissions projecting in the Federal Republic of Germany and in the United States.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS *(This Report)*	21. NO. OF PAGES 76
	20. SECURITY CLASS *(This page)*	22. PRICE PC A05 MF A01

EPA Form 2220-1 (9-73)

AIR POLLUTION EMISSIONS PROJECTING

A Report of the NATO/CCMS Pilot Study
on Air Pollution Assessment Methodology and Modeling

COMMITTEE ON THE CHALLENGES OF MODERN SOCIETY
NORTH ATLANTIC TREATY ORGANIZATION
October 1978

Preface

The North Atlantic Treaty Organization (NATO) established the "Committee on the Challenges of Modern Society" (CCMS) at the November 1969 meeting of the North Atlantic Council.

The CCMS was charged with developing meaningful environmental and social programs that complement other international programs, and with showing leadership, first, in solution of existing problems and, second, in development of long-range goals for environmental protection in the NATO sphere of influence and in other countries as well. A first Pilot Study on Air Pollution was initiated by the CCMS at its inaugural meeting in December 1969. The United States (Environmental Protection Agency) has been the pilot nation with the Federal Republic of Germany (Federal Ministry of the Interior) and Turkey (Scientific and Technical Research Council) as copilot-nations.

The Pilot Study on Air Pollution was an action program designed to demonstrate and encourage the utilization of existing knowledge for the development of air quality management programs. It entailed the demonstration of a system approach to air quality management. Case studies have been carried out in Ankara, Turkey; Frankfurt, Federal Republic of Germany; St. Louis, U. S.; Oslo, Norway; South Holland Region, The Netherlands (NATO/CCMS Report No. 6, Appendices A - E).

The results of the pilot study are documented in NATO/CCMS Report No. 6 (Revised) "Guidelines to Assessment of Air Quality" of October 1972 and in NATO/CCMS Report No. 33 (Final Report) containing 15 recommendations as well as in several other documents, listed as Annex II to this document.

Starting from three of the above recommendations (VI, VII and XIV) the Federal Republic of Germany proposed to initiate a new Pilot Study on Air Pollution Assessment Methodology and Modeling at the CCMS Plenary Session on October 22 and 23, 1974.

These NATO/CCMS Recommendations are:

RECOMMENDATION IV

Member nations will co-operate to develop standardized methods for emissions data storage and retrieval to support requirements in the conduct of national air quality management programs. The US National Emission Data System (NEDS) might serve as a model for a common international system.

RECOMMENDATION VII

Member nations will co-operate to develop standardized techniques for projecting emissions and predicting future ambient air quality.

RECOMMENDATION XIV

Member nations agree the CCMS modeling activity has shown that there is a widespread need for further international co-operation to accomplish the following tasks:

- Bring together model developers and air quality managers for exchange of ideas, discussion of users' needs and demonstration of modeling techniques.
- Standardize modeling techniques for specific air quality management applications and consider how computerized models might be made available for all users.
- Continue to review on-going air quality assessment studies.

In spring 1975 the North Atlantic Council approved the German proposal. The pilot study work started with the Federal Republic of Germany (Federal Ministry of the Interior) as pilot nation and the United States of America (Environmental Protection Agency) and Belgium (Service du Premier Ministre) as co-pilot nations:
A Working Group and two Panels were established with the following functions:

Assessment Methodology Panel

- Pursue and carry out Recommendations VI and VII
- Continue to review present and future assessment studies with respect to the application of assessment methodology.

Modeling Panel

- Develop standardized models for various air quality management applications.
- Develop programs to improve modeler/user communications in conjunction with the Assessment Methodology Panel and the Working Group.
- Continue as an information forum on new modeling concepts and techniques, organizing once a year international technical meetings on air pollution modeling and its application.

In addition the Working Group established an Ad-Hoc Group on Air Quality Management Systems to revise and update the NATO/CCMS Report No. 6 (Revised) 1972 by preparing a new document on "Guidelines to Air Quality Management Systems".

Another Ad-Hoc Group was set up for compiling a Glossary of Terms frequently used in assessment methodology, modeling and air quality management systems.

As an outcome of this Pilot Study on Air Pollution Assessment Methodology and Modeling the following NATO/CCMS documents are published (see also Annex III):

Air Quality Management System

- Guidelines to Air Quality Management System.

Assessment Methodology

- Air Pollution Emission Inventory Systems
- Air Pollution Emissions Projecting

Air Pollution Modeling

- Introduction to Air Quality Modeling
- Uses and Needs for Air Quality Modeling
- Bibliography on Grey Literature on Air Quality Modeling, Part I (Applied Models)
- Bibliography on Grey Literature on Air Quality Modeling, Part II (New Modeling Techniques)
- Practical Demonstration of Multiple Source Urban Air Quality Modeling (Gaussian Plume)
- Fundamentals for the Applications of a Gaussian Plume Model

Other Publications

- Glossary of Terms
- Proceedings of the 6th International Technical Meeting on Air Pollution Modeling and its Application (24. - 26. September 1975, Frankfurt/Main, Germany)
- Proceedings of the 7th International Technical Meeting on Air Pollution Modeling and its Application (7. - 10. September 1976, Airlie House, USA)
- Proceedings of the 8th International Technical Meeting on Air Pollution Modeling and its Application (20. - 23. September 1977, Louvain-la-Neuve, Belgium).

The chairman of the Working Group wishes to acknowledge the scientists participating from pilot, copilot, and observer countries, and the many other persons, who assisted in the preparation of this document.

The panel, which performed diligently throughout the course of this effort, receives the highest praise. The panel members were:

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The addresses of the panel members are listed in Annex I.

Full recognition is given to each panel member for carrying out and coordinating review and other activities related to the development of this document in his respective country and to Ms. C. Morawa of the Federal Environmental Office, Germany for her effort in coordinating and organising and for editorial work.

For the Working Group,
Erich Weber, Chairman.

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1. Introduction

This document is concerned with alternative emission projection techniques and describes the relationship of emissions projecting to the Air Quality Management System (AQM). Based on the experience of several NATO countries, principles are given for applying the projecting techniques to the available emissions inventory data bases and to the other data required. The Appendix presents detailed methodology for emissions projecting in the Federal Republic of Germany and in the United States of America.

2. General

2.1 Alternative Methods of Estimating Future Emissions

Projecting future levels of emissions involves a wide range of possible activities. The simpliest procedure involves the application of generalized growth factors to current production or emission levels for general sources categories, whereas comprehensive emission projecting requires regional demographic projections, detailed land use growth factors, and quantitative methodologies to depict the complicated interrelationships between industrial categories. Past and present emissions can also be used independently (via statistical techniques) to project future emission trends. This method, however, is not generally appropriate and has proved inadequate for both planning purposes and for focusing attention on likely problem areas.

Emission forecasts, both in principle and practice, involve the future estimates of two independent parameters: activity rates and the net emissions associated with each unit of those activity rates. Population, production rates, and energy

consumption are examples of activity rates that must be estimated by the forecaster for the selected geographical area. These activity rates are then transformed into anticipated emissions via "controlled" emission factors[+)] which are the quantities of emissions actually discharged for each unit of activity. This parameter includes the probable, future-like pollution control efficiency and changing technology for each source category. The projected activity rate is multiplied by this value to obtain the total emissions. For example, a 30 % increase in total cement production might be anticipated between 1975 and 1985. Through knowledge of current and impending pollution control legislation and an estimate of the relative mix of wet and dry cement kilns in 1985, the forecaster determines the controlled emission factor (e. g., the net emission rate per unit of cement production). These two items are multiplied together to yield the total emissions from cement manufacturing that are expected in 1985.

It should be emphasized that some countries (e. g., FR Germany) define emission factors as the net release of atmospheric emissions whereas others (e. g., U.S.) utilize the concept of uncontrolled emission factors. In the latter case, controlled emissions are calculated by separately including the effect of the expected control efficiency. Both approaches are entirely suitable for purposes of emission inventories and emission projections.

+) Emission inventorying techniques normally use uncontrolled emission factors whereby the existing control efficiencies are separately applied for each individual source. In projecting, however, the major influence on emissions is the degree of expected and enforceable performance standards. These are generally written as maximum emissions allowed per unit of activity or process throughput. For this reason it is easier and more logical to compile a future, "controlled" emission factor to multiply against an industrial category's future activity level.

2.2 Responsibilities in Forecasting

As discussed later in this paper, in-depth forecasting first requires a detailed and accurate emissions inventory for the geographical areas of interest. Thus comprehensive emissions forecasting is usually undertaken by mature air pollution control agencies with an established grasp of their local problems. Moreover, there is a direct need for interdepartmental data (i. e., expected traffic growth and land use patterns); for this reason accurate forecasting is usually accomplished at a lower level of administrative control, (e. g., those agencies responsible for one to two million population). In this manner, the probable changes and patterns in emission levels are immediately available for investigating alternative control strategies to solve the local problems.

Emissions forecasting must also be conducted at the national level because nationwide decisions are continually being made on a day-to-day basis. Responsibilities of the national program are threefold; to provide a uniform set of procedures, formats and guidelines for local agencies to use in forecasting emissions; to transmit projections to the local agencies on the expected effects of national and regional control programs (e. g., future emission factors for automobiles); and to maintain a back-up or default forecasting system in the event that local agencies are not sucessful in their forecasting efforts. It is also important to recognize that demographic, economic, and industrial growth data are often collected on a routine basis by centralized nationwide agencies. Such information can often be obtained directly from these agencies in a machine-readable format. This makes the information ideal for incorporation directly into the forecasting system and for transmittal to the appropriate local agencies for their use.

2.3 Relationship to the AQMS

Within the framework of an overall air quality management system, detailed forecasting methodologies are needed only after assessment has been truly accomplished (and an up-to-date emissions inventory is available). At this rather mature stage of program development, emission forecasts not only provide future estimates based upon today's strategies, but also is an ideal mechanism for comparing effects of various control strategies. Thus, emission forecasting is a vital management tool and has an integral role in the planning and evaluation activities of control agencies.

2.4 Uncertainties of Forecasts

Successful forecasting depends as little as possible upon historical patterns and emission trends. Rather, it relies heavily on externalized predictors of population, industrial growth, life styles, effects of current control strategies, and probable technological developments. Uncertainties in these factors invariably introduce errors into the forecasts and may be extremely difficult to quantify. Statistical confidence in these input parameters improves as the forecasting time period decreases and is likely to be fairly accurate for up to three to five years. Fortunately, this is generally adequate for evaluating pollution control strategies and for taking any corrective management action.

3. Uses of Emission Forecasts

3.1 Macro-Forecasting

The macro-forecasting concept is generally useful only for large, homogeneous geographical areas. Summary emission statistics for generalized source categories are usually

obtained through the macro-fore-casting technique; these statistics are then used primarily in decisions associated with the total air management system. Emission estimates are calculated as a first approximation having moderate precision and used in overall management decisions involving reallocation of resources within the general air quality management system. They are also useful in evaluating long-range strategies involving the development and application of "what if?" scenarios.

One advantage of macro-forecasting is the usual availability of activity growth parameters from established branches of the national government that deal routinely with demographic, economic, and energy data. Such references are often also used in calculating emissions for the current emissions inventory and thus their projections are also applicable for the emission forecasting effort. It should be recognized, however, that adjustment and assumptions must sooner or later be made in transforming economic or energy parameters to emission projections. For example, national forecasts for future sales of coal may be assumed to be equivalent to coal consumption and used accordingly in emission projections. Such assumptions are necessary, yet all must clearly be detailed in the methodology so that the forecasts can routinely be updated as new data become available. This updating capability is especially important when the original emission forecasts are compared with the actual emissions inventory and appropriate adjustments made to the second generation of forecasts. The capability of such adjustments allows the AQMS to apply forecasts with assurance that they are correct and to adjust priorities accordingly. Utilizing these forecasts, the AQMS can periodically reallocate resources to those programs having the largest emission-reduction potentials.

3.2 Micro-Forecasting

Emission forecasting of very small geographical areas or even individual sources has been found to be valuable in plant siting studies, local land-use planning, and in preparing environmental impact statements for highway construction and other public works projects. In determining the impact of contemplated projects, the micro-forecasting techniques invariably yields higher precision data than the macro-forecasting method. Obviously, however, this techniques is more expensive to implement and is most applicable to short-range, local forecasting. Results of micro-forecasts in conjunction with the detailed source inventory provide details that are readily used as data for direct input air pollution dispersion models.

Usually micro-scale forecasting is more effectively conducted or evaluated by the local pollution control agency. This is true because local topography, meteorology, zoning regulations, and other regional considerations are highly important variables in micro-forecasting. Also, emission projections and expected impact on air quality are part of environmental impact statements and permit applications. For this reason, standard formats, calculation procedures, and outputs should be formulated by the local agency as soon as possible, preferably before micro-forecasting becomes an implied part of their reporting requirements. Due to the high costs of micro-forecasting, this activity is probably limited to established pollution agencies representing 2 - 3 million inhabitants.

4. Needed Data and Capabilities

4.1 Baseline Emissions Inventory

Emissions inventories are generally composed of three categories of emitters: point, line and area. In the most detailed inventories, a large fraction of the emission total is represented by the point/line source data base. Thus the comprehensive inventory contains many data items for a large number of individual emitters. Some countries, such as the Netherlands, incorporate forecasting data on individual facilities directly into their baseline emissions inventory. Until such sophistication is reached, however, most emissions are likely to be determined by the area source data base whereby individual emitters are represented by a relatively few, aggregated categories.

Many data items for a few sources is one characteristic of micro-forecasting due to the small geographical area involved and the high accuracies expected. Impact of current emission laws must be determined for each source and incorporated into the baseline inventory, preferably as a function of equivalent control efficiencies. Future activity rates are obtained from the sources themselves via surveys or in conjunction with routine enforcement/testing efforts. Thus, while the current source inventory may include a large number of data items regarding a particular source, only three additional items are needed to forecast emissions from that source: the future year, the operating rate for that year, and the expected equivalent control efficiency. This concept is also easily applied to area source categories such as mobile sources and residential fuel consumption. For such sources, equivalent control efficiency may actually

represent the fuel-mix or low-sulfur regulations whereby the activity rate indicates a composite growth parameter such as total residential fuel demand.

The above discussion assumes that extensive work has been done in obtaining correct data for the current inventory and that all major sources are included in the data base. This is especially important in micro-forecasting small geographical areas where the absence of only a few sources in the current inventory can lead to large errors in forecasts. The importance of all point sources being represented in the inventory decreases significantly as the geographical area of interest becomes larger. In the transition from micro to macro-forecasting, incompleteness in the point source inventory is often corrected automatically by adjustments to the area source inventory. In the U.S.A. this self-correction occurs through the initial use of aggregated activity rates and subsequent apportioning to point and area source contributions. For example, in the U.S.A. the total, national consumption of coal is known through routine publications: the total coal consumed by all point sources in the emission inventory is calculated and automatically subtracted to yield the coal contribution from area sources.

Macro-forecasting utilizes an aggregated emissions inventory that is intrinsically free from local variations in activity rates (e. g., traffic patterns) that dramatically affect the micro-forecasting of local areas. Automobile usage, for example, is easily obtained nationally and inherently more accurate than for a city or other small area.

4.2 Other Data Needs

Successful forecasting requires the collection and use of data other than the baseline emissions inventory. Many of these exogenous inputs are also used, directly, or indirectly, to calculate and apportion emissions in the current data base; and the identical algorithms can also be applied to the forecasting methodology. There are five basic categories of information utilized in emissions forecasting. These data must all be filtered past the question: "What is the realistic estimate (the anticipated situation) as opposed to what is hoped will occur (the proposed situations)?"

Census and Economic Information:

Anticipated demographic and industrial growth rates are vitally necessary to forecasting and, fortunately, are generally easy to acquire from the national government. These references are commonly used to compile the current inventory and therefore conversion procedures are already established for use in the forecasting efforts.

Effects of Existing and Proposed Regulations:

Including the effects of pollution regulations is best incorporated into the emission forecasts by using equivalent control efficiencies and projected activity growth rates for given source categories. The most stringent emission limitations should be applied (local, regional, or national), however caution is advised to differentiate between a proposed timetable for compliance compared with the probale percentage of sources that will meet the law in a given year. People are usually overly optimistic and believe that existing laws will take effect much more quickly than actually

occurs. This is particularly true in estimating the impact and time schedule of proposed regulations and it is adviseable to be especially conservative in this area. The true relationships between time spans and emission reductions may be successfully reduced from historical legislation and previous emissions inventories.

Control Technology:

Process changes and emissions control technology are often difficult to estimate but must be considered, especially for new facilities yet to be constructed. Emission reductions are most cheaply achieved by implementing performance regulations for new sources rather than by extensive controls on existing sources of pollution. For this reason, the established air quality management system will eventually consider legislation requiring best available control technology to be utilized by new facilities. The effects of developing technology of new source performance standards are gradual and may not be significant when short-term emission forecasts are compiled.

Emission Factors:

Emission factors relate emissions of a specific source category (without emission controls) to an operating rate. The concept and use of emission factors is absolutely necessary in compiling a comprehensive baseline inventory and is also essential in macro-forecasting where measured emission data are not available. Controlled emission factors can also be developed for processes to be constructed at some future time (e. g., coal liquification) for use in forecasting emissions.

Local Data:

The fifth and last category of forecasting data encompasses land use zoning, transportation control strategies, and alternative siting locations for new plants. These considerations are strictly local in nature and applicable only for micro-forecasting. The influence of such factors depends entirely on lateral coordination within local governmental bodies such as between the pollution control agency and the regional planning commission. Employing these factors to modify air pollution levels and patterns in the community requires a highly developed, integrated program that can be achieved only after a long period of time and effort.

4.3 Form and Content of Forecasts

To facilitate comparison, it is preferable that forecasted emissions are in exactly the same format as the current emissions inventory and that they both have the same detailed and summary capabilities. Whether manual or automatic reporting is used, the same analysis capabilities must be available to both current and forecasted emissions. In fact, micro and macro results may both be required for modeling the predicted pollutant concentrations. Thus both the macro-scale (summary statistics) and the micro-scale (detailed source statistics) data are utilized in good air pollution control management.

Time scales of micro and macro data requirements must also be considered in forecasting emissions. Usually, summary statistics are presented as annual emissions and forecasted emissions must be compatible and over the same time duration. In addition to these requirements, micro-scale statistics must predict seasonal fuel use, industrial production, and transportation statistics to facilitate interpolation to

hourly emission rates needed for atmospheric dispersion modeling. The forecasting system must also be able to predict emissions for all pollutants in the current existing emissions inventory for each comparison with the current data.

4.4 Validation of Forecasting Methodologies

Continual review and revision of the selected forecasting system is highly desirable and can be accomplished in a number of ways. One meachanism is to compare the previously forecasted emissions with the actual outcome shown by the emissions inventory. For this to occur, the forecasting system must be operational for at least two years. If it is seen that major deviations (± 30 %) exist between the predicted and actual emissions, this usually indicates that improper growth factors are being applied to some emission categories and that revisions are needed. For example, anticipated population forecasts may be used in the forecasting system to estimate changes in emissions of organic solvents. Validation of the system may reveal that growth in hardware retail sales (e. g., paint) is a more appropriate growth parameter than population data. Of course, values for these new parameters must always be realistically available and the forecasting system must be suitably flexible to accommodate such substitutions.

Another means of validating and correcting the forecasting system is to devise parallel forecasting systems for comparative purposes. This is generally done by comparing emission projections of different organizations for their own purposes. For example, the regional pollution control agency might use local traffic/planning data to forecast emissions which can easily be compared with predictions from the nationwide forecasting system to evaluate differences and subsequently reconcile these variations.

5. Resource Considerations

The resources required to forecast emissions depend entirely upon the priority and importance placed on the results by the AQMS. Once the methodology is developed and procedures standardized, a macro-forecast at the national level will require little time and effort. In the U.S.A. such results are utilized in national trends documents and to indicate expected progress of the national air management program. Micro-forecasting, however, might require much more time to complete for each regional area. It is therefore generally advisable to encourage different levels of effort in micro-forecasting so that the first "rough" forecasts can direct the area of emphasis in the subsequent, more sophisticated micro-forecasts.

There are three functional areas associated with micro-forecasting that are especially resource intensive. The first, improvement of the current emissions inventory, is generally necessary because many errors or gaps will become evident upon close scruting. The second, obtaining projected activity rates and equivalent efficiencies for individual point sources, can effectively be accomplished only via door-to-door surveys of the emitters. The third resource - intensive activity is the acquisition of local planning and transportation information and the subsequent synthesis of such data into tabulation of expected growth rates.

ANNEX I

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ANNEX II

NATO/CCMS Documents on the First Air Pollution Pilot Study (available at: NATO/Committee on the Challenges of Modern Society, NATO Headquarters, Brussels, Belgium)

AIR POLLUTION (No. 5)

Proceedings of the 2nd Meeting of the Expert Panel on Air Pollution Modeling, (26 - 27 July 1971, Paris, France) Out of stock

AIR POLLUTION (No. 6)

Guidelines to Assessment of Air Quality (Revised)

APPENDIX A	Assessment of Air Quality in Ankara (February 1973)
APPENDIX B	Assessment of Air Quality in St. Louis (February 1973)
APPENDIX C	Assessment of Air Quality in Frankfurt (June 1974)
APPENDIX D	Assessment of Air Quality in Oslo (February 1973)
APPENDIX E	Assessment of Air Quality in South Holland Region (December 1973)

AIR POLLUTION (No. 7)

Quality Criteria for Sulphur Oxides (November 1971) Out of stock

AIR POLLUTION (No. 8)

Air Quality Criteria for Particulate Matter (November 1971) Out of stock

AIR POLLUTION (No. 10)

Air Quality Criteria for Carbon Monoxide (June 1972)

AIR POLLUTION (No. 12)

Control Techniques for Sulphur Oxide Air Pollutants (October 1975)

AIR POLLUTION (No. 13)

Control Techniques for Particulate Air Pollutants (October 1973)

AIR POLLUTION (No. 14)

Proceedings of the 3rd Meeting of the Expert Panel on Air Pollution Modeling
(2 - 3 October, 1972, Paris)

AIR POLLUTION (No. 15)

Air Quality Criteria for Nitrogen Oxides (June 1973)

AIR POLLUTION (No. 18)

Control Techniques for Carbon Monoxide Emissions from Stationary Sources (October 1973)

AIR POLLUTION (No. 19)

Control Techniques for Hydrocarbon and Organic Solvent Emissions from Stationary Sources (October 1973)

AIR POLLUTION (No. 20)

Control Techniques for Nitrogen Oxide Emissions from Stationary Sources (October 1973)

AIR POLLUTION (No. 29)

Air Quality Criteria for Photochemical Oxidants and Related Hydrocarbons (February 1974)

AIR POLLUTION (No. 30)

Proceedings of the 4th Meeting of the Expert Panel on Air Pollution Modeling, (28 - 30 May 1973, Oberursel, Germany)

AIR POLLUTION (No. 33)

Final Report (May 1974)

AIR POLLUTION (No. 35)

Proceedings of the 5th Meeting of the Expert Panel on Air Pollution Modeling (4 - 6 June 1974, Roskilde, Denmark)

AIR POLLUTION (No. 41)

First Follow-up Report (December 1975)

AIR POLLUTION (No. 50)

Second Follow-up Report (December 1976)

AIR POLLUTION (No. 67)

3rd Follow-up Report (November 1977)

Annex III

NATO/CCMS Documents on the Pilot Study on Air Pollution Assessment Methodology and Modeling
(available at: NATO/Committee on the Challenges of Modern Society, NATO Headquaters, Brussels, Belgium)

Air Pollution (No. 42)

Proceedings of the 6th International Technical Meeting on Air Pollution Modeling and its Application
(24 - 26 September 1976, Frankfurt/Main, Germany)

Air Pollution (No. 51)

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Bibliography on Grey Literature on Air Quality Modeling, Part I (Applied Models)

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Glossary of Terms Generally Used in Air Pollution Assessment Methodology and Modeling

Air Pollution (No.)

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(20 - 23 September 1977, Louvain-la-Neuve, Belgium)

Air Pollution (No.)

Air Pollution Emission Projecting

Air Pollution (No.)

Introduction to Air Quality Modeling

Appendix A

AIR POLLUTION EMISSIONS PROJECTING IN GERMANY

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1. Introduction

The 1971 environmental program of the German Federal Government necessitated a fundamental reorganization of the immission protection legislation. Not only were necessary measures for safety precautions provided in this reorganization as in the past, but also precautionary environmental regulations when the Federal Immission Protection Act[+)] went into effect in 1974, the legal part of the reorganization was concluded.

The goal of preventive environmental protection is to create a means of immission protection by far-sighted planning by taking into account as early as possible certain air quality requirements especially in conjunction with zoning plans on the regional and Länder level. In this manner, an optimal relationship is attained between the benefit of environmental policy and economic costs. Only through far-sighted measures will it be possible to achieve environmental protection together with justifiable expenditures. The Federal Immission Protection Act includes a legal establishment of the principle of preventive environmental protection, and it strives for systematic improvement of environmental relationships by reviewing the sources of harmful environmental effects. Prerequisite to such a plan of action is comprehensive collection of data on present environmental patterns, as well as the recognition of the continued development of harmful emissions and immissions in regards to the region under study. Prognostication of emissions which comprises some kind of technological forecasting will be required as an instrument to collect such information.

+) Bundes-Immissionschutzgesetz; Law for the Prevention of Harmful Effects on the Environment caused by Air Pollution, Noise, Vibration and Similar Phenomena, of 15 March 1974.

With regard to the technological prediction, it is required that only those methods be employed that furnish results with acceptable error probability while their expenditure can still be justified. Technological forecasts are always based on certain regularities, which have been determined by past observation. For this reason, no sudden fluctuations can be foreseen. Thus, trend functions are considered, while rising and falling market fluctuations cannot be taken into account. As a result, technological forecasting cannot be complete and exact, and furthermore, it is limited in regard to the depth of its findings.

If the results of such prognoses are to be used as a basis for decisions affecting the future, such data must be correctly evaluated. This includes, above all, a knowledge of action domains and boundary conditions. The period of time to be covered by the forecast must remain surveyable, but it should not be too brief.

2. Formation of the Problem: Purpose and Goals of Emissions Forecasting

Emissions prognoses will be made for various problems; for example, statements can be expected on the following:

- The development of yearly emissions of various harmful substances in the Federal Republic of Germany during a specific period.
- The development of yearly emissions of individual harmful substances for relevant emitter categories or branches of industry in the Federal Republic of Germany, during a specific period.

- The development and future relevance of harmful substances for relevant emitter categories or branches of industry in the Federal Republic of Germany, during a specific period.

- The development and future relevance of harmful substances in limited regions, for example individual states (hereafter designated Laender) of the Federal Republic of Germany, especially in defined Areas with Heavy Pollution Load (AHP)[+)] during a specific period.

Statements such as these will provide the basis for:

- early recognition of developing environmental problems; the condition of such problems in planning, whether it concerns new industrial areas, transportation patterns or residential areas.

+) (Belastungsgebiete), see Art. 44 Fed. Imm. Prot. Act:

Article 44

Findings in Areas with Heavy Pollution Load

(1) In order to determine the extent and development of air pollution in Federal territory and to obtain a basis for remedial and precautionary measures, the authorities competent under Länder laws shall, in areas with heavy pollution load as definded in paragraph 2, continuously establish the nature and extent of certain types of air pollution in the atomsphere which may cause harmful effects on the environment, and shall examine the conditions that are conductive to the development and spread of such air pollution

(2) Areas with a heavy pollution load shall be areas in which air pollution occurs or is to be expected, which, owing to

1. its frequency and duration,
2. its high concentration, or
3. the danger inherent in combinations of different types of air pollution,

may cause particularly harmful effects on the environment. Areas with a heavy pollution load shall be determined by ordinances issued by the Länder governments.

- recognition of those areas crucial to future emission control - relevant pollutants, emitter groups, processes - for which special measures of prevention or reduction of emissions have to be developed, also within the framework of Clean Air Plans[+);

- evaluation of the effectiveness of measures planned with the framework of Clean Air Plans.

- creation of possibilities for a goal-oriented commitment of public funds; for example, the support of processes with reduced environmental impact, which brings about certain positive developments and hinders others.

The basic goal of such forecasts is the accumulation of comprehensive data on future developments on the origins and distribution of air polluting substances.

[+)] (Luftreinhalteplan), see Art. 47 Fed. Imm. Prot. Act:

Article 47

Clean Air Plans

The findings pursuant to Article 44, paragraph 1, and the emissions inventories shall be evaluated, taking into consideration the meteorological conditions. If the evaluation shows that harmful effects on the environment occur, or can be expected to occur, by air pollution within the whole or parts of areas with a heavy pollution load, the authority competent under Laender laws shall draw up a Clean Air Plan for that area. The Clean Air Plan shall contain the following details:

1. nature and extent of established and expected air pollution and of the harmful effects on the environment.
2. findings as to the causes of the air pollution, and
3. measures to reduce or prevent air pollution.

Since, as a rule, financial resources are limited, only certain selected objectives will be pursued. Thus the volume of such investigations and the methods employed are determined by the goal to be attained. Main directions can be indicated by the following topics:

Topic 1

Knowledge of nationwide, supraregional or global developments of the most important pollutants, in order to harmonize air purification techniques with industrial and technical progress, and, in consequence, the initiation of legal regulatory measures at the Federal level.

Topic 2

Coordination of regional planning with projected environmental conditions in order to warrant a sufficiently high air quality also in congested areas and AHP's.

Topic 3

Avoidance of direct conflict situations at the local level by means of preventive measures as a prerequisite for the undisturbed realization of medium and long-term industrial expansion.

These concepts about the major goals of emission forecasting include a geographic limitation. Thus Topic 1 limits itself to the area of the Federal Republic of Germany as a whole; Topic 2 refers to questions concerning the individual Laender, and also specific areas within these Laender; while Topic 3 deals with the local level. This regionally oriented system proceeds from a problem statement of general relevance to one concerning the specific situation of individual industrial firms.

Table 1 shows the three-tier system of emissions forecasting. The scheme shows which information sources are available for emissions prognoses, what type of information can be expected from the prognoses, and which conclusions can possibly be drawn in order to attain the goals on the individual level. Furthermore, the table shows that one level can remain isolated; rather, an active excange of information is necessary between all levels. This applies particularly to the middle level, as developmental tendencies must generally be deduced from forecasts on a Federal basis, since general statistics are not sufficient on a Laender or regional (AHP) level, and because general projections for these areas are not available at all.

3. Determination of Emission Forecasts

Emission rates (E) are usually determined by combining rates of consumption or production of certain products (M) with a proportionality factor, which defines the specific emission rate (e) of a substance during a definite procedure and at a specific operating plant, i. e.:

$$E = e \times M.$$

Thus it is necessary to determine production or consumption rates on one hand, and emission factors on the other. While for small regions it is complicated enough to get data on past production and consumption (which are necessary for producing trends and serving as base data for the determination of prognoses), there arise severe difficulties if data on future developments are requested. A few topics of common interest on the Federal level; for example, energy production, automotive transportation, and population growth, are regularly forecast and published and are relatively easy to obtain.

In forecasting for medium and small-sized areas, it is necessary that prognoses be available in the form of trend developments for the individual Laender as a means of orientation parameters; and that constructive cooperation by industry be provided in order to adapt the general trend to that of a specific area. Especially with regard to the small area, i. e. the local level, it is necessary to ascertain future plans of individual companies.

The emission factors are to be used in forecasting as weighted average values, which must consider progress of abatement technology. These factors are in no way applicable to the individual installation. They should be determined as weighted averages, valid for a certain period, usually one year, and for all plant types and all possible emission sources under consideration. Futhermore, these factors must be normalized in such a way that they can be converted to yearly emission rates on the basis of the corresponding statistical consumption and production figures.

3.1 Methods for Establishing Emission Forecasts

Starting points in determining emission forecasts are usually product or consumption prognoses, which basically represent trend extrapolations from previous time series. After that, the availability of relevant, comprehensive data is the next prerequisite for forecasting. Since previous data were not collected from an environmental standpoint, the basis of emission forecasting is still very incomplete. Topics concerning environmental protection are, however, of increasing interest in the field of statistics, i. e. individual, pertinent investigations are being undertaken. The statistical data basis is most comprehensive on the Federal level for the Federal Republic of Germany. Furthermore, there

are prognoses and programs available for certain topics in this area, notably energy production. Energy forecasting (which includes expected economic growth, population development, etc.) is conducted regularly on the Federal level. Forecasts are also regularly published on the development and status of motor-vehicles; these are based on the expected general economic growth. On the basis of such data, it is possible to formulate an emission forecast for a large area such as the Federal Republic of Germany. In such a forecast, the development of several, especially relevant and widely distributed pollutants is of interest; the subsequent association of these substances to various emitter categories is of special importance. Here average values, which take overall technological development into account as much as possible, will be used as emission factors. On the other hand, it seems wise to consider those developments which are strictly induced by legal measures. Such a prognosis can provide information on emissions only. Emission data which apply to the entire Federal Republic of Germany are not applicable to the evaluation of the Federal Republic of Germany's air quality situation. Consequently, information about the foreseeable development of air pollution cannot refer to the whole Federal Republic of Germany. Such statements are only meaningful in the context of smaller areas, especially AHP's.

The data basis, i. e., prognoses and time series from the past, diminishes according to the size of the region. Statistics are collected on the Laender level, but these are not sufficient to serve as a basis of emission forecasting; for example, even energy balance sheets are not available for each Land. Thus, there is even less reason to expect sufficient information on specified areas of a given Land, e. g., those whose AHP's boundaries do not correspond with statistical, administrative, or political borders. In these areas, it seems possible to reach a conclusion in two ways:

- through a direct investigation of the actual situation combined with interviews on the companies' medium-term developmental plans, and
- through the adjustment of nationwide development tendencies to the pertinent region, while considering particularities of the region.

Each method taken alone has its problems. The inquiries alone result in unjustifiable expenditures, and furthermore, would burden many an entrepreneur. This method would surely be suitable for the local level of the three-tier forecasting scheme: direct conflict situations connected with concrete plans for expansion could be recognized and alleviated in this manner. Whenever time series from the past several years have been compiled on the basis of repeated emission inventorying, it may be possible to calculate emission prognoses by using electronic data processing. The second approach requires a careful analysis of the area with respect to which forecasting data available on the Federal level may be transferred to this specific area. If necessary, more extensive classification must be undertaken in order to achieve patterns which finally are comparable.

As a solution to the problem, a combination of both approaches is suggested in order to come to a first approximation. It is not to be expected that all relevant fields can be included in emission forecasting.

4. Emission Forecasting as a Component of Clean Air Plans

Through the Federal Republic of Germany's Immissions Protection Act, Articles 47 and 44, the legislative body delegated to the Laender governments the responsibility of formulating

Clean Air Plans. Among other things these plans are to include the type and extent of air pollution to be expected. In this manner forecasting is linked to an administrative procedure and in the last analysis loses its model character predominating so long. For the first time in the Federal Republic of Germany, a Clean Air Plan was formulated for the AHP "Rheinschiene Sud" (Cologne region). The preliminary work, especially relative to emissions inventorying had been most advanced for this area. There was no doubt, however, That the Clean Air Plan could not be based on a complete emission forecast. To begin with it, it was necessary to answer the question concerning type and number of the relevant harmful substances which were to be considered in the following investigations. Furthermore, inquiries regarding those emitter categories had to be made for which emission forecasts would be feasible because of a sufficient data basis. From the very beginning, however, it was evident that there were no field for which the required time series were available. But finally household and commercial furnaces and ground transportation emitter categories were selected as suitable. Both fields are characterized by millions of individual emission sources which are uniformly distributed in the area, and whose emissions originate near the ground. Their further development is closely correlated to population growth as well as to general economic growth; these factors could be correlated to the Federal level, for which a body of corresponding prediction was available.

4.1 Emitter Category: Households and Small Consumers

For this category, the results of emission inventories were established as a basis with respect to a given reference year. This group, however, is composed of many heterogeneous parts - including private households, institutions, public facilities, commercial and trade enterprises, laundries, con-

tracting companies and farms. Even the available statistical data for the Federal level do not permit an exact breakdown of overall consumption for the individual sectors. Estimates carried out by energy companies concluded that approximately 2/3 of the overall consumption went to private households. Because no energy assessments are available for the region under consideration nor even for North Rhine-Westphalia, direct comparisions with the Federal level could not be made. In order to make estimates of energy consumption by households and small consumers on a regional level, new ground had to be broken. The extremely narrow statistical basis did not permit a comprehensive and unlimited application of the prognostic procedures employed for energy forecasting. Out of necessity, a procedure had to be chosen which was well supported by data of the responsible local authorities and of utility companies. An energy requirements prognosis, corresponding to the development of the specific energy requirement in the Federal Republic of Germany, and to the development of population and number of dwellings in the AHP was computed on the basis of the consumption rates of the individual energy carries in the entire AHP as well as in its central regions. Because the emissions inventory included only emitting energy carriers, additional investigations were necessary for the consumption of electricity and district heat. These must be considered as energy supply substitutes in the overall development.

In order to execute the forecasting procedures, the variables of future energy consumption had to be estimated: residential population, number of dwellings and energy consumption per dwelling. Local authorities supplied data on expected population growth, number of persons per dwelling, construction of new dwellings, remodeling and demolition of existing dwellings. Future energy consumption per dwelling, as well as consumption of electricity and district heating, were estimated

on the basis of projected development at the Federal level, since relevant previous data for the study area were not available. In order to evaluate future energy consumption by energy carriers, the forecast took into account detailed information supplied by utility companies regarding possible development of various energy carriers.

First, future consumption trends were estimated for pipe-dependent energy carriers for which concrete estimates, if not definite purchasing contracts, were available. After that, the consumption of solid-fuel material was estimated. The consumption of light fuel oil was calculated as the remaining portion of overall consumption.

Between 1960 and 1974, in the Federal Republic of Germany, energy consumption per dwelling (independent of temperature variation) increased, on the average, by 3.4 %. The determining factors for this increase were increased heating comfort, the enlargement of the heated area per dwelling, the conversion from room to central heating, as well as relatively low energy costs. The trend in the past could best be described by a logarithmic linear time function of the type

$$\log y\,(t) = b \cdot t.$$

An extrapolation of this trend, without adjustments, was no longer admissible due to changes in the energy market since 1973/74. It was expected that consumption increasing influences in the past would continue, though weakened, in the future. However, the increase was savings through better insulation and increased energy costs, which might amount to around 10 % in 1980 and 20 % in 1985. The correction of the trend reduced the average growth of energy consumption to 1.3 %. A corresponding development was introduced for consumption of electricity: this led to reduction in growth from 12.2 % on an average in the period 1960 - 1974, to 6.2 %. in the forecast period.

The use of coal and of light fuel oil for individual furnaces will continue to decrease. The calculated growth rates were correspondingly transferred to the AHP, while peculiarities of this region were taken into consideration.

The conversion of energy consumption to yearly emissions was carried out for the reference year using emission factors known from previous investigations and which were determined recently on the basis of comprehensive surveillance measurements. Regarding further development in the forecast period, it was concluded that the essential improvements in the combustion of solid fuels had been achieved in the past and that this level will be maintained in the future due to control measures. With respect to liquid and gas fuels, further improvements in the forecast period, based on approximately optimum combustion conditions, were also considered.

4.2 Emitter Category: Automotive Transportation

The emission prognosis for this field referred solely to pollutants released during the combustion process in the various combustion engines, either directly introduced by the fuel or originating as a result of the process. Emissions caused by tire or brake wear were not included.

The results of the emissions inventory of a specific year of reference, supplemented by additional statistical data, provided the basis for the emission forecast. The number of motor vehicles, the traffic pattern and special emission factors determined by test stand experiments served as identifying parameters.

The motor vehicle population in the Federal Republic of Germany has been predicted in the past by several authors. Prognoses were also available for a development region, which included the AHP. Thus, an adaptation of these results to the AHP appeared to be possible. Transportation forecasts were made with adjustments similar to those investigations done on the Federal level. The waste gas legislation, both extant and planned, provided the basis for extrapolating emission factors for the forecast period.

Existing prognoses by various authors which applied to the Federal Republic of Germany were converted into a motor-vehicle population forecast. This forecast considered parameters important for the generation of emissions, such as type of vehicle, type of propulsion, piston displacement, age and weight of the vehicle. Another relevant parameter is the mileage. For this reason, in addition to the population prognosis, the development of average mileage within the forecast period was estimated. As a basis for the vehicle population prognosis on the Federal level, data on the parameters affecting emissions published by the Federal Automotive Authority (Kraftfahrt-Bundesamt) was used. Further information was furnished by the Federal Road Institute (Bundesanstalt für Straßenwesen). With respect to the average mileage by car types, publications by the Federal Ministry of Transportation (Bundesverkehrsministerium) were available. Motor vehicles were classified in three basic groups:

- Passenger cars including station wagons,
- Commercial vehicles, such as trucks, buses and licenseable tractors,
- Licenseable motor cycles.

Due to their limited number mopeds were not included in the study.

The fraction of diesel-engine passenger cars and station wagons increased steadily, but 96 % of all vehicles were still propelled with spark-ignition engines. It was estimated that the fraction of diesel-engines, buses and tractors are almost 100 % so equipped. For this reason, it was calculated that trucks would also show an increase in the use of diesel-engines during the forecast period.

The average age of passenger cars and trucks remained fairly constant in the past, so that no change in the average age of vehicles was expected in the future. Thus the age distribution was rated corresponding to that of the previous five years.

There was a pronounced decrease in the mean mileage of passenger vehicles, a trend which was projected in the prognosis. The opposite trend was observed for commercial vehicles.

In order to apply data of the Federal level to the AHP, the following criteria were decisive:

- The degree of motorization, i. e. number of vehicles per inhabitant, came very close to that on the Federal level.

- In the AHP, the distribution of vehicles according to age, and the distribution of passenger and commercial vehicles according to type of propulsion and weight, corresponded to the patterns on the Federal level.

In both cases, Federal patterns could be taken as representative. The fraction of the vehicle population in the AHP relative to that on the Federal level was presumed to remain constant.

Traffic prognoses were preceded by a detailed analysis of the actual traffic situation. Based on results of traffic analyses, the traffic rate was extrapolated by a trend function for the projected time period, and the estimated characteristic traffic data were correlated to data obtained from the emissions inventory. Both the AHP and surrounding areas were observed in detail. Thus drivers who live in surrounding areas and work in the AHP and thus contribute decisively to the flow of traffic were also included. The following types of traffic were differentiated in the investigation area:

- traffic within the area
- destination-bound traffic
- transit traffic.

The analysis of traffic within the area and of the destination-bound traffic demonstrated that 70 % consisted of individual traffic, i. e. the predominant percentage of the overall mileage was due to passenger vehicles. Trucks were only of minor importance in the AHP-traffic.

Overall mileage can be described as the sum of mileage performed by all motor vehicles. Partial mileages were produced in the line sources (main arteries) and area sources (remaining traffic flow) into which the study area had been divided. Traffic loads were taken into consideration in the emissions inventory by means of representative diurnal variations. The yearly mileage of a given line or area source were calculated by adding the mileages per time intervall over all hours of the year. The yearly mileage for the entire area was obtained by adding the mileages of all sources.

The traffic analysis showed that the product between total vehicle population and average mileage is a suitable parameter for calculating trends of traffic development. Based on the prediction of motor vehicle population, overall mileage in the AHP was predicted with the help of average mileage. But an adjustment of the vehicle population growth rates was necessary, due to the influence by a predetermined saturation level on trend development. It was assumed that the saturation level would finally adjust to the point of one passenger vehicle/household. The growth rate of privately motivated traffic served as a correcting factor in the trend prognosis for overall mileage.

The traffic prognosis which was determined in this manner provided the basis for evaluating emissions produced by motor vehicles. Emissions are directly proportional to traffic load (number of vehicles per hour) and to the emission factor dependent on driving mode (mass of pollutant per vehicle and hour); and inversely proportional to average driving speed. The emissions inventory supplied the diurnal variation in traffic load and the pertinent average driving speed for each line and area source. Superimposing all line and area sources of one year provided a representative diurnal variation of the AHP's mileage. The summation over all hours of the day led to an average total diurnal mileage and in proportion to the diurnal mileages of line and area sources. With respect to the prognosis, it was assumed that the relative diurnal variations in mileage for the entire AHP would not change significantly. Also the driving mode distribution in the diurnal variations had to be considered constant, i. e. it was assumed for the first order approximation, the mode of driving would remain unchanged.

The emission factor of a pollutant is the average value of emissions produced by a motor vehicle calculated from a spot check. It is dependent upon the average driving speed (driving mode). The spot check was executed in such a way that it gave representative values, with respect to the statistics of the vehicle: type, age, piston displacement, power, running performance and weight. These characteristics were assigned to each separate emission determination within the spot check.

Partial emission factors were determined for given vehicle age groups. Taking into account the time dependent change of the age distribution a prognostic function was determined.

The future development of emission factors is influenced by a large number of parameters, the total effects of which can hardly be prognosticated. The following essential influencing factors were considered within the framework of the prognosis:

- the age distribution of passenger vehicles in the Federal Republic of Germany,
- the waste gas legislation and its effects on the real emission properties of passenger vehicles.

Two groups of harmful substances were reviewed separately:

- Harmful substances created as secondary combustion products from additives or impurities in the fuel.
- Harmful substances which are produced during combustion in the chemical reaction of a hydrocarbon-air mixture.

For the first group it was assumed that the legally prescribed reduction rates will completely affect the emission factors, since the respective emissions are dependent only upon the fuel consumption of the vehicles.

For the second group this impact is more difficult to evaluate. For this reason, the Europe-Test results of each inspected vehicle were referred to the prescribed series test values for each vehicle class. Deviations were then transferred correspondingly to all other driving modes. Under these conditions emission factors relating to the distance covered were calculated as a function of the average driving speed.

The expected emission rates of automobile traffic were calculated for each individual pollutant on the basis of forecast mileage and forecast emission properties. It was postulated that the percentage of mode-related mileage would not change in the AHP during the forecast period.

4.3 Emitter Category: Industry

For short-term and medium-term future development of industrial emissions, a centralized system provides an information base of emissions of planned installations subject to licensing, and is already working in parts of the Federal Republic of Germany. After the announced commencement of the installation's operation, data are transferred to the emissions inventory which guarantees continuous updating of the data base.

Through this updating of the emissions inventory and by means of annual revision of the data base by compiling copies of the data tapes, time series will emerge which provide a valuable basis for prognostic calculations. Thus usable time series will not be available before several years. Data taken from permit applications will provide information not only on capacity expansion, but also on technical developments in the field of control technology. Thus from this point of view, a time-dependent adjustment of emission factors appears possilbe.

In another AHP, a particulate matter emission forecast was attempted for iron and steel production. The basis of this study is an emission forecast already available for a larger region, the respective Federal Land, which had in turn been deducted from a productions forecast at the Federal level. This method was chosen since a large part of the iron and steel industry in the Federal Republic of Germany is concentrated in this AHP and it consequently seemed acceptable to make use of overall emission factors.

In this instance, the Federal Land production prognosis had to be transferred to the AHP. Herein the ratio of steel production in the AHP to the Land's steel production was taken to remain constant during the projected period. Figures for pig-iron production were derived from the production of crude steel, increased by foundry requirements. The transport of pig-iron across AHP boundaries had also to be taken into consideration, since the total pig-iron required was necessarily produced within the AHP. From the production of pig-iron sinter production and the consumption of iron ore were dedected.

Yearly emission rates were computed by using emission factors for individual production fields; these are to be understood as weighted averages over all types and kinds of processes and installations. For the forecast period, it was postulated that the portion of controlled exhaust fumes in the essential areas of blast furnace operations and steel production will continue to be increased and that consequently emission factors can be expected to decrease.

5. Conclusion

The legal part of reorganizing the immission protection provisions was concluded when the Federal Protection Act was ratified. The strategic concept behind this reorganization advances the ideas of preventive environmental protection more than it did in the past. Nevertheless, there were earlier attempts to develop methods which would permit contemporary recognition of future environmental problems, making it possible to initiate appropriate preventive measures to avoid such conflicts. The tool to recognize future environment problems is forecasting emissions: This is based primarily on the prognosis of consumption and production developments on one hand and on the ascertainment of pertinent emission factors on the other.

An overall emission forecast, i. e. one which covers all pollutants in a given area, cannot be carried out because the expenditures required for such an undertaking would not be justifiable. Only a limited number of selected pollutants can be examined in connection with the one or more characteristic emitter categories, (e. g. branches of industry). According to different goals, the formulation of the question for such a prognostic investigation can be very variable. Investigations conducted to date have led to the formulation of a three-tier-scheme, which is designed for a hierarchy of problems ranging from general relevancy to the specific situation of individual industrial firms.

The mayor goals of this scheme are:

- coordination of air pollution control technology progress of production technology,

- coordination of regional planning with the expected environmental situation in order to guarantee a sufficiently high level of air quality even in heavily polluted areas,

- avoidance of direct conflict situations on the local level.

The methods for formulating emissions forecasts are diverse, ranging from a pragmatic approach based on published data on production and consumption, through mathematical models, to direct interviews with companies. Very often, the various methods must supplement each other. Due to the Federal Protection Act, emissions forecasting, in conjunction with the preparation of Clean Air Plans for AHP's is implicated within administrative procedures. As a rule, the AHP region is too small to allow evaluation of generally accessible statistical data. With respect to heating facilities of individual households and small consumers, as well as motor vehicle traffic, the application of new forecasting methods was tried. Both categories are characterized by numerous installations, distributed over the entire areas. Based on this fact, a direct connection with the structure of the pertinent larger region, which possessed a more comprehensive data base (statistics) and for which prognoses for certain categories were available, was attempted. The starting point was a one-year emissions inventory, supplemented by statistical data and information gathered by direct surveys. After a thorough analysis of the individual areas, emission forecasts could be formulated for both categories, while general trend developments were adjusted by special information obtained from the AHP.

Due to the establishment of emissions inventories in AHP's and to updating these inventories with periodic revisions, time series which can serve as a starting basis for the application of mathematical prognostic models as produced. Centralized recording and evaluation of permit applications for installations subject to licensing provides direct information on the emissions of planned facilities. Thus, medium-term projections of emissions from licenseable plants may be determined from the updated emissions inventory. As a final result of this approach, inventory for AHP will be available in the near future.

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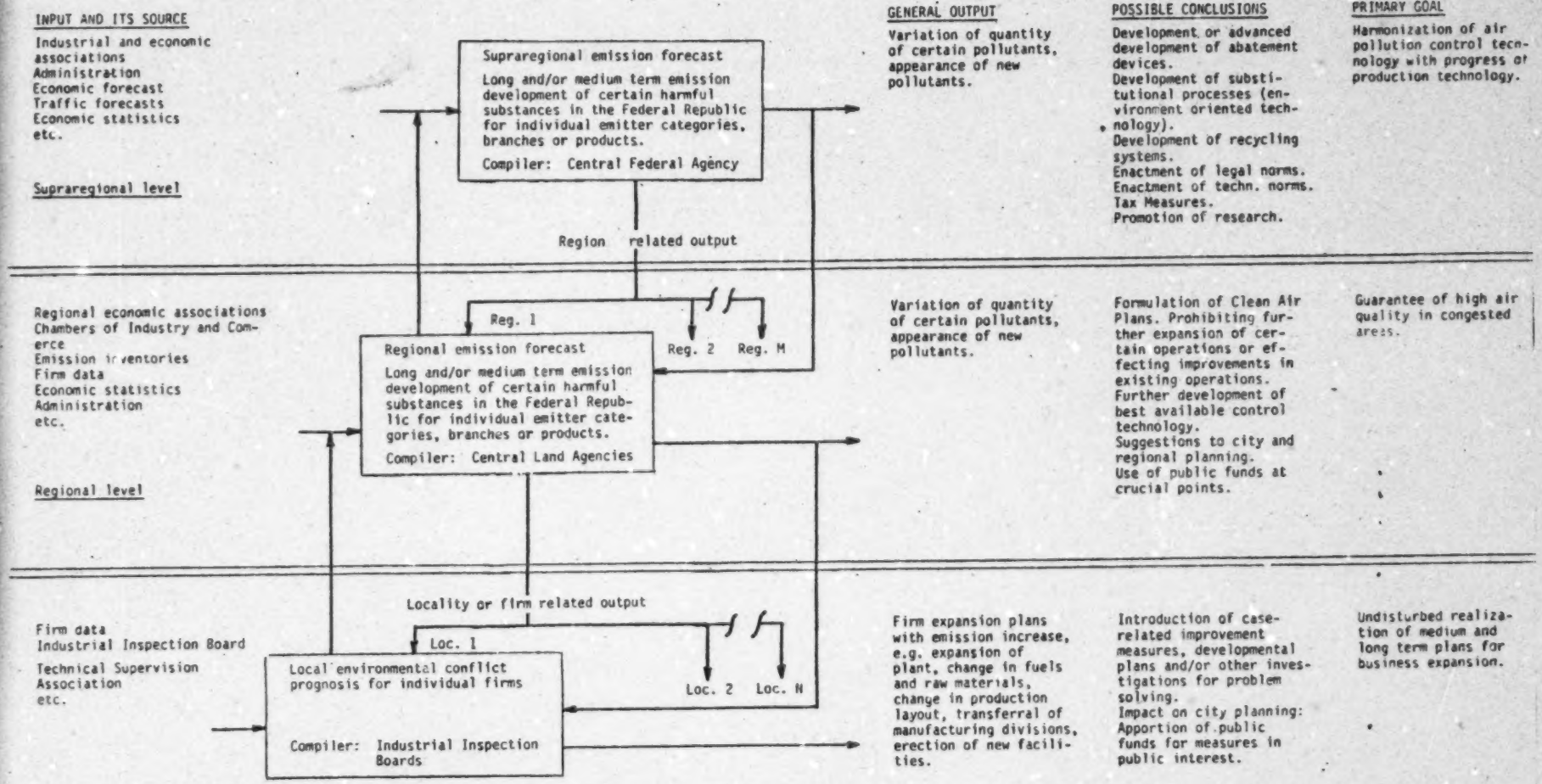
Table 1

Scheme of a three-tier-system of emission forecasting


INPUT AND ITS SOURCE
Industrial and economic associations
Administration
Economic forecast
Traffic forecasts
Economic statistics
etc.
Supraregional level
Supraregional emission forecast
Long and/or medium term emission development of certain harmful substances in the Federal Republic for individual emitter categories, branches or products.
Compiler: Central Federal Agency
Region related output
GENERAL OUTPUT
Variation of quantity of certain pollutants, appearance of new pollutants.
POSSIBLE CONCLUSIONS
Development or advanced development of abatement devices.
Development of substitutional processes (environment oriented technology).
Development of recycling systems.
Enactment of legal norms.
Enactment of techn. norms.
Tax Measures.
Promotion of research.
PRIMARY GOAL
Harmonization of air pollution control technology with progress of production technology.
Regional economic associations
Chambers of Industry and Commerce
Emission inventories
Firm data
Economic statistics
Administration
etc.
Regional level
Reg. 1
Reg. 2
Reg. M
Regional emission forecast
Long and/or medium term emission development of certain harmful substances in the Federal Republic for individual emitter categories, branches or products.
Compiler: Central Land Agencies
Variation of quantity of certain pollutants, appearance of new pollutants.
Formulation of Clean Air Plans. Prohibiting further expansion of certain operations or effecting improvements in existing operations.
Further development of best available control technology.
Suggestions to city and regional planning.
Use of public funds at crucial points.
Guarantee of high air quality in congested areas.
Locality or firm related output
Loc. 1
Loc. 2
Loc. N
Firm data
Industrial Inspection Board
Technical Supervision Association
etc.
Local environmental conflict prognosis for individual firms
Compiler: Industrial Inspection Boards
Firm expansion plans with emission increase, e.g. expansion of plant, change in fuels and raw materials, change in production layout, transferral of manufacturing divisions, erection of new facilities.
Introduction of case-related improvement measures, developmental plans and/or other investigations for problem solving.
Impact on city planning: Apportion of public funds for measures in public interest.
Undisturbed realization of medium and long term plans for business expansion.
Local level

Appendix B

AIR POLLUTION EMISSIONS PROJECTING IN THE U.S.A.

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1. Purpose of Forecasting Emissions

Standardized techniques for projecting or forecasting pollutant emissions are particularly crucial and necessary when an air quality control program becomes fully operational. By that time, the air quality monitoring networks and an ongoing emissions inventory program have been established and can routinely provide data for managers to use in their strategy development and air quality modelling activities. In the United States, standard forecasting techniques became absolutely necessary when EPA's Air Quality Maintenance Program required State agencies to maintain acceptable levels of air quality when specified pollutant concentrations were reached through the national abatement control program. Thus, in 1973, EPA began to develop standard methodologies to forecast annual emission levels for use by both EPA and local air pollution control agencies.

2. Basic Input Parameters for a Comprehensive Emission Inventory Forecasting Methodology

A complete emissions inventory system must be available so that economic growth expectations can be applied to the present activity levels of industrial sources or industrial categories. In the U.S., the National Emission Data System (NEDS) provides the following input parameters:

(1) Individual annual throughput (activity levels) for more than 100,000 point sources in the U.S. together with their annual emissions and equipment pollution control efficiencies.

(2) Annual emissions and activity levels associated with over fifty categories of area source emitters in all 3200 counties within the U.S.

The standard formates of NEDS provides the emission forecasting methodology with common emission input parameters for a variety of geographical areas (i. e., nationwide, State, county). It is important to recognize that the NEDS system is entirely independent and has its own updating mechanism, edit/validation checks, and retrieval programs. This allows the emission forecasting methodology to routinely use one or more of the standard NEDS outputs without concern for the internal functions of the system.

3. Econometric Functions

The emissions inventory provides current source/emissions data; economic and population growth rates must then be applied to estimate future production rates. These economic growth rates are usually compiled by a centralized Federal agency and, unfortunately, often do not correlate directly with industrial categories of air pollution. Thus, cross-reference tables must be generated so that the defined appropriate economic growth rate can be applied to each emitting source in the emissions inventory data base.

In the U.S., projected economic activity to the year 2000 is routinely published by the U.S. Department of Commerce in their "OBERS" projections. These forecasts are made nationally, by State, and by Standard Metropolitan Statistical Area (SMSA) as defined by the U.S. Census Bureau. In addition to population and employment growth, OBERS forecasts projected earnings in constant dollars for 37 industrial and commercial categories. The computerized OBERS files provide the economic input parameters to EPA's emission forecasting models.

4. Existing and Proposed Emission Control Laws and Regulations

The effect of pollution control regulations (existing and proposed) on source emissions is a variable that dramatically affects future emissions. The NEDS emissions inventory system, previously described, contains the maximum allowable emissions for each source under the most stringent regulation and the year that the law is scheduled to become effective. This information on each source is directly used by the forecasting methodology.

5. General Emission Projection Equations

The two general equations for calculating point source emissions are:

(Emission) = (Activity) x (Uncontrolled Emission Factor)
x (1 - Control Efficiency)

(Emission) = (Activity) x (Uncontrolled Emission Factor)
x (Sulfur/Ash Content x 1 - Control Efficiency)

For process emissions, the estimated activity level (e. g., throughput) for future years should ideally be forecast by the facility operating the process. If this is impossible, techniques are available to determine future activity levels for individual processes by applying generalized industrial growth patterns (e. g., OBERS). The pollutant removal efficiency required for a given future year, however, cannot logically be obtained from the polluting facility since such a number is solely a function of the legal requirements placed on the source by the most stringent pollution control regulations. Thus, the values for future process control efficiencies and for allowable ash/sulfur content must generally be calculated

directly from the most stringent control polices, regulations, and compliance schedules. Anticipated emissions reductions due to the most stringent applicable regulations are converted into a single, equivalent control efficiency for each point source. This equivalent control efficiency value for the process, one for each projection year, also reflects the authorized time-table for achieving compliance with the regulations.

Uncontrolled emission factors for each process are independent from the control equipment actually installed in a given facility. These uncontrolled emission factors are inherent to each process and remain constant from year to year. Thus the same emission factors used for calculating base year emissions can be used in the equation for calculating.

6. Two EPA Systems for Forecasting Regional Emissions

EPA has developed a computerized system to forecast emissions for each Air Quality Control Region (AQCR) in the U.S. The Regional Emission Projection System (REPS)[1] directly accesses the NEDS (source inventory) and OBERS (economic growth) data banks and automatically produces either an emission summary report or point source listing for any given year between 1974 and 2000.

A manual technique[2] for forecasting emissions has also been developed and published by EPA. This technique utilizes the familiarity of local pollution control and planning agencies with their specific geographical areas.

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[1] Environmental Protection Agency, Office of Air Quality Planning and Standards, Regional Emission Projection System, February, 1975, (EPA-450/3-75-037).

[2] Environmental Protection Agency, Office of Air Quality Planning and Standards, Guidelines for Air Quality Maintenance Planning and Analysis, Vol. 7: Projecting County Emissions, Second Edition, January, 1975, (EPA-450/4-74-008).

The REPS system and the manual technique for projecting emissions are summarized in the remainder of the paper. A comparison of methods of projecting emissions in a selected geographical area has been performed by the U.S. EPA.[3]

7. Regional Emission Projection System (REPS)

Future emissions are projected by the REPS system based on three sources of input data:

(1) Economic and demographic forecast data from the SEAS system[4] and the OBERS projections.[5]

(2) Base year emissions inventories and related data from the EPA National Emissions Data System (NEDS).

(3) Additional data supplied by the system user.

The three steps in the projection methodology are:

(1) Determining regional growth factors for pollution producing activity.

(2) Projecting present emissions inventories to the future.

(3) Adjusting the emission projections to include the effect of required emission controls.

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[3] Environmental Protection Agency, Office of Air Quality Planning and Standards, Comparison of Four Methodologies to Project Emissions for the St. Louis Metropolitan Area, October, 1975, (EPA-450/3-75-074).

[4] Environmental Protection Agency, Office of Research and Development, Prototype Development of the Strategic Environmental Assessment System (SEAS), April 1974, Draft.

[5] U.S. Department of Commerce, Bureau of Economic Analysis, Projections of Economic Activity for Air Quality Control Regions (OBERS Projections), August, 1973.

7.1 SEAS Projection Data

The projections of national industrial growth by sector, as developed by the SEAS system, were used for a number of reasons:

(1) The data are obtained from a sophisticated and widely accepted input-output model of the national economy and the accuracy of the projections was, therefore, felt to be relatively high.

(2) Substantial industrial detail is available because 284 economic sectors are represented in the econometric model.

(3) The SEAS data are especially valuable for projection emissions because the SEAS system models the effects of material and fuels substitution, technological innovations and industrial process changes. These factors are all critical for predicting future levels of emission-producing activity.

7.2 OBERS Projection Data

The OBERS regional economic projection are used to regionalize the SEAS forecasts. Although this approach involves several basic assumptions and certainly introduces some degree of error in the final results, it was adopted for two basic reasons:

(1) The OBERS projections, developed by the U.S. Department of Commerce, are based on extensive local data accumulated by the U.S. Government, some of which are confidential or proprietary and which are consequently not available in other projection models.

(2) The OBERS tapes are one of the few sources of regional projection data available at the AQCR level directly.

The SEAS projections are given in terms of total gross output; the OBERS projections in terms of earnings. Both data are in terms of constant dollars, which eliminates the effects of inflation and permits real growth factors to be computed. In regionalizing the SEAS projections of gross output, a scaling factor from OBERS, based on projected growth in sector earnings, is used. Although the relationship between output and earnings will not necessarily be uniform throughout the country or even within an AQCR, it is felt that this assumption does not introduce any severe errors.

Also fundamental to the projection methodology is the assumption that the growth as computed from the SEAS and OBERS projection data is proportional to growth in pollution-production activity such as plant throughput. In addition, the REPS methodology is based on the assumption that relative prices of industrial products will remain static. This assumption may introduce errors if the prices of exhaustible mineral and energy resources increase substantially relative to other industrial products, but it is difficult to estimate the magnitude of the error with any degree of confidence.

7.3 NEDS Regional Emissions Inventory and Related Data

The NEDS inventory contains the following types of data for point sources:

(1) Base year emissions.

(2) Emissions permitted by existing regulations and compliance with these regulations.

(3) Operating data for new plants expected to become operational in the future.

The area source inventory defines the levels of emission-producing area source activity; it does not contain emission data explicitly.

Two data sources related to the NEDS inventory are used by REPS in developing the emission projections. One is the compilation of emission factors as published in EPA document AP-42.[6] The other is a summary of Federal New Source Performance Standards (NSPS) which govern emissions from new and retrofit industrial equipment. This summary includes standards already promulgated in the Federal Register, as well as proposed standards were supplied by the Emission Standards and Engineering Division of EPA's Office of Air Quality Planning and Standards.

The NEDS system is used in REPS because it contains all the data required for projecting a complete emissions inventory. In addition to net base year emissions for existing point sources, it contains data concerning both base year emission regulations and future point sources, as previously defined. The data are referenced by AQCR, and the format of the data is uniform from region to region. Since the projections are produced in this data format, they are compatible with any of the NEDS summary programms or air quality models.

A detailed description of all the sources of data mentioned previously and a comprehensive explanation of how those data are used to develop projections of activity and emissions are discussed in detail in II-3 through II-6 of EPA-450/3-75-037 (see footnote 1).

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[6] Environmental Protection Agency, Office of Air Quality Planning and Standards, Compilation of Air Pollutant Emission Factors, Second Edition, March, 1975, (EPA-AP-42).

8. The Manual Technique to Forecasting Emissions in small Geographical Areas

The purpose of the technique is to provide a set of specific procedures for estimating future air pollution emissions from point and area sources in an individual county or in any comparatively small geographical area. A uniform reporting format enables the results from a number of countries to be aggregated to the SMSA or AQCR level. Since future emissions are determined by the level of activity in the country, the pollution projections are based on estimates of economic and emographic growth. These projections are developed for each specified county and are established independently of potential growth in emissions from neighboring counties. In addition, the impact of emission abatement regulations and compliance schedules is included in the calculation of emissions.

8.1 Summary of the Approach

The instructions provide estimating procedures to be completed by county or other local government representatives. A limited familiarity with air quality data analysis and analytic techniques such as graphical extrapolation and curve fitting is presumed. The emphasis in the development of the projection methodologies and translation of these methodologies into a coherent set of manual instructions has been on simplicity and clarity with a minimum sacrifice of validity.

The technique is designed to specifically provide for local initiative and data input. This is an extremely valuable feature for a number of reasons. The personnel at the county-equivalent level responsible for completion of the manual will in many cases have most immediate access to some of the

best data for making growth projections. Local data can be used when the user feels them to be more accurate or timely than published state or national data. There is great variation among counties as far as categories and depth of data and projections available; the user is encouraged to use the references he feels are more appropriate, even if they are not cited explicitly in the instruction. There is also provision for substitution of local emission factors for those published by EPA.

There are a number of distinct advantages associated with such a projection technique which builds up from the local level. The technique is based in large part on local information (much of which might be unpublished and unofficial), which in many cases can provide the best estimates of local growth. Since the projections are to be made by local or regional officials, with knowledge of local partices, the opportunity has been provided to override emission factors or other standard statistics, and to use parameters or data which are considered more accurate for their jurisdiction. The task of relating projected activity levels to emissions, requires a review of all laws and regulations that apply to any sources in the county. The effect of emission controls is quite significant in forecasting emission levels, because while activity growth for many sources will remain below five or ten percent per year, control regulations may well require a decrease in emissions of 50 percent or more.

8.2 Emission Source Categories

The manual details the baseline and forecasted emissions calculations for each of the following source categories:

Industrial processes
Fuel combustion

Transportation
Electricity generation
Incineration
Miscellaneous

8.3 Industrial Process

This section deals with point sources categorized under industrial process emissions. Industrial fuel combustion is not included in this category.

Emission factors for process emissions are given in terms of levels of output or production, and in many cases are functions of industrial process used to produce that output. There are thirteen subcategories of industrial process emissions:

Chemical manufacturing
Food/agriculture
Primary metals
Secondary metals
Mineral products
Petroleum industry
Wood products
Evaporation
Metal fabrication
Leather products
Textiles
Inprocess fuel
Other

The probable growth rates for each of the above categories are available from disaggregated national data (e. g., OBERS).

Each subcategory, however, is comprised of many individual, different processes. Therefore, it is logical to assume that each process within the county will be reviewed on an individual basis and the emissions calculated separately. This requires a detailed point source inventory for the entire geographical area.

Data required to complete the industrial process projections are obtained through interviews with industrial and commercial organizations to determine their plans for facilities expansion. Projecting future point source emissions involves not only projecting changes in activity levels, but also includes the effects of emission control regulations to be implemented in the future. The procedure recommended for including future controls in the projections is given in the manual and involves calculating the eqivalent removal efficiency based on externally uncontrolled emissions. In addition, point source emission projections include four other considerations:

1. Early compliance to new source performance standards.
2. Variance from emission regulations.
3. Replacement of operating equipment due to obsolescence.
4. Increase in plant output with no change in plant output capacity (i. e., a change in utilization of existing capacity).

The following instructions are given for projecting industrial emissions (using the table numbers from EPA 450/4-75-008) (see footnote 2):

1. From the data gathered during the industrial interview program determine a growth factor for each projection year for each SCC process and enter in Table 1.4. One Table 1.4 must be completed for each projection year.

2. From data on applicable control regulations and aided by the industrial interview program, determine the equivalent control efficiency required for each pollutant, for each SCC process, for each projection year. Enter results in Table 1.4.

3. From the interview program, determine expected total throughput for each point source SCC process from all plants in each projection year, and enter in column 4, Table 1.4. For each individual point source, compute projected emissions based on projected throughput, emission factors, and the future required emission control. Aggregate emissions for all processes in each emission category, total, and enter in Table 7.2.

4. If projected throughput data cannot be determined from interviews, emissions for each individual point source may be projected based on net emissions and control in the base year, the growth factor for the SCC, the emission factor, and the future required emission control. Aggregate emissions for all processes are summarized and reported in Table 7.2.

8.4 Fuel Combustion

This section deals with emissions (both point and area source) due to the direct combustion of fuels. External combustion refers to stationary, off-highway equipment, such as gas turbines and reciprocating engines.

Emission factors are given in terms of the fuel burned. The fuels which are considered include:

1. Major fuels:

   Coal (antracite, bituminous, lignite)
   Heating oil (distilate, residual)
   Natural gas

2. Minor Fuels:

   Process gas
   Coke
   Wood
   LPG
   Bagasse
   Other

Fuel combustion emissions are projected by first determining the future fuel energy demand (in BTU's) and then apportioning that demand to the fuels which are likely to be used. The manual provides the following instructions for determining BTU demand:

1. Convert the county baseline fuel use to BTU equivalents. To do this it is necessary to add up the BTU's for both point and area source combustion of each fuel. Since the BTU content of fuels shows substantial variation regionally, use the BTU equivalent which is appropriate for the region in question. Then compute the projected BTU demand as follows:

   a. Residential. Determine the projected increase in dwelling units in the county, based on zoning plans, land-use plans, and housing studies. Use this data to produce growth factors for the projection years. Adjust the growth factors to reflect any change in the average number of rooms per dwelling unit, based on expected new construction. This could be determined by the proposed dwelling unit: home, townhouse, apartment, etc.

b. Industrial. Use the results of the interview program with the major industrial fuel users in the county to obtain data for the baseline year and for any industries which are considered likely to be major polluters in the projection years. The latter can be identified from county industrial growth plans, or from interviews with the present major polluters.

c. Commercial/Institutional. Obtain growth factors from this sector by conducting an interview program with the major commercial fuel users similar to the industrial interview program above.

8.5 Transportation

The following sources are considered in estimating emissions resulting from transportation activity:

Highway vehicles. There are five vehicles which are the major sources of pollution:

(1) Light-duty gasoline vehicles (LDV), automobiles, which account for most transportation emissions.

(2) Light-duty gasoline trucks (LDT); these are less than 8500 pounds gross weight.

(3) Heavy-duty gasoline vehicles (HDV); these are greater than 8500 pounds gross weight.

(4) Heavy-duty diesel (HDD)

(5) Gasoline motorcycles (MC)

The manual provides the following instruction to project emissions for light-duty vehicles (LDV):

(1) Obtain estimates for future county vehicle-miles-traveled (VMT) for each of the five vehicles types from county transportation or highway studies. Determine this data for each projection year.

(2) The age distribution of county LDV and the annual mileage driven by the vehicles of each age group must be considered to produce weighted emission factors for LDV. The equation for the weighted emission factor e_{np} for calendar year (n) and pollutant (p) is:

$$e_{np} = \frac{\sum_i (c_i \times d_i \times f_i \times t_i)}{\sum_i f_i t_i}$$

Where:

i = age of vehicle

c_i = the federal test emission factor for the model year corresponding to vehicle age (i) at low mileage

d_i = the controlled pollutant (p) emission deterioration factor for model year (i) at calender year (n)

f_i = fraction of total vehicles in use of age (i)

t_i = average annual miles driven by vehicle of age (i)

(3) To project emissions for LDV, multiply the baseline VMT by the weighted emission factors (e) and any speed correction factors necessary.

Procedures similar to those above are provided in the manual to project emissions from off-highway mobile sources, railroads, vessels, and aircraft.

8.6 Electricity Generation

This category covers point source emissions from electricity generation by power utility companies. Both internal and external combustion equipment are considered. Although the emissions from these sources are substantial, the estimation of present and future emissions is made easier by the fact that comparatively good fuel data is kept for power plants, and growth is planned well into the future. Emission factors are given in terms of quality of fuel burned and the sulfur and ash content of that fuel.

The forecasts will be based on available data on new power plant sites and anticipated fuel type. Such data is available for the nearterm (less than 10 years) but is more speculative for the long-term. Interviews with the power utilities in the county are the best source of such data. Because emissions will increase abruptly when a new fossil fuel plant comes on line, it is essential to determine as precisely as possible the year in which that will occur. The procedures to be used in preparing the electric generation emissions forecast are as follows:

(1) Estimate the amounts of each fuel which will be burned (both internal and external combustion) to produce electricity in the projection years, and determine the sulfur and ash content of this fuel, if applicable, by interviewing the power companies in the county.

(2) Convert the future fuel use data to emissions by muliplying by:

   a. The emission factor.
   b. The sulfur or ash content, if applicable.
   c. The equivalent control efficiency required by future emission regulations.

8.7 Incineration

This category includes point source emissions from government incineration (which means any large-scale operation by federal, state, municipal, or local government); point and area source emissions from industrial and commercial/institutional incineration; and residential area source incineration. The two primary disposal methods are open burning and on-site incineration; most other disposal methods, such as landfill, are replacing open burning and do not produce air pollution. Emissions are calculated from the tons of waste burned.

The manual provides the following instructions to project emissions from incineration:

(1) For each projection year, determine growth factors for each source and each disposal method. The best source of this information is direct contact with agencies and organizations responsible for the large point sources. In addition, consult county or state solid waste studies and land-use plans for data concerning expected changes in solid waste levels and disposal methods.

(2) Multiply baseline solid waste by these growth factors, and apportion to disposal methods.

(3) To compute future emissions, multiply projected solid waste by emission factors for the projected years. For point sources, also multiply by the equivalent control efficiency required in the projection year to meet emission standards. When computing emission factors, include all local knowledge and data about proposed regulations concerning incineration and open burning.

8.8 Miscellaneous

This category covers any area sources not included in other categories. These miscellaneous sources are characterized by intermittent emissions which may be substantial at times and are frequently regional in nature. Two specific evaporative sources are considered--hydrocarbon evaporation from the handling of gasoline (primarily at the retail filling station), and evaporation from the use of solvents (specifically in dry cleaning processes, surface coating operations, industrial solvent use not covered by point sources, and miscellaneous solvent use); evaporative emissions from industrial point sources and bulk gasoline terminals are considered under industrial processes. Emission factors are based on the amount of gasoline sold (in gallons) and the amount of solvent used (in tons).

The follwoing instructions are provided to project evaporative emissions:

(1) Gasoline. Determine future gasoline in the county from one or more of the following sources:

a. County or state energy office.
b. County or state tax agency.
c. Transportation studies.
d. Gasoline dealers association surveys.

If none of the above sources contain the necessary information, use total projected gasoline vehicle miles and divide by 12.2 miles per gallon to produce gasoline use. Multiply by the emission factor for gasoline evaporation to obtain projected emissions.

(2) Solvents. Scale baseline solvent use by the population growth factor for the projection years. Multiply by the emission factor for solvent use to obtain projected emissions.